WATER and OUR FORESTS

Water controlled is a friend

Water in flood is a foe

Agriculture Information Bulletin No. 71
Formerly Miscellaneous Publication No. 600
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

FOREWORD

Water, like air, is accepted by man as a matter of course, and he seldom stops to think that without it life would be utterly impossible. Only in times of drought or flood does he appreciate its true significance. Then he realizes that if it is to become a willing servant, he must learn to understand and control its behavior from the time it reaches the earth until it empties into the sea.

Upland forests are one of Nature's most important means of regulating and maintaining the flow and quality of water. How these forested slopes are managed determines whether the rain and snow they receive will be a blessing or catastrophe.

Each locality looks to the forest for special services; each has its special water problems. Whatever these needs or problems are, we cannot overlook the importance of healthy, forested watersheds. It is up to man to restore, protect, and manage these watersheds in order to gain the manifold services they offer—adequate water supplies, protection against flood and erosion, numerous forest products, an ideal habitat for wildlife, and attractive recreational facilities.

Lyle F. Watts

Chief, Forest Service.

WASHINGTON, D. C.

Issued March 1946
Slightly revised December 1951

WATER AND OUR FORESTS

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Water, the Lifeblood of Civilization

WATER is the priceless resource on which all growing things depend. It is the lifeblood of civilization.

Where there are ample supplies of good water, vigorous nations can flourish. Farms thrive, cities prosper. When the supply of water fails, farms are abandoned, communities are imperiled, and cities and cultures die, leaving crumbling ruins to mark their past glory.

In the United States the bulk of the population, most of the large cities, and the major part of the cropland and forested areas are located in regions of over 20 inches of annual rainfall. In parts of the drier Western States there are relatively few towns or cities; usually they cluster around the limited available water supplies derived from high mountain forests (fig. 1). Not until we reach the more humid Pacific Coast, with its towering forests, do we again find enough water to support large cities and industries.

The city dweller of the humid East, accustomed to unstinted quantities of water for drinking and cooking, bathing and washing, and sprinkling lawns and gardens, encounters few of the difficulties that beset the inhabitants of western plains and semidesert communities. Yet even he is sometimes brought face to face with local water shortages, resulting from low supplies in reservoirs or in streams that feed his water mains. Year in and year out, the eastern farmer confidently expects enough rain to bring through his crops. Only

[1]The authors gratefully acknowledge the contributions of the following members of the U. S. Forest Service: E. N. Munns, Chief, Division of Forest Influences, for his stimulating guidance and valuable suggestions and criticism; Gordon R. Salmond, Chief, Division of Watershed Management, and T. W. Norcross, Chief, Division of Engineering, for many helpful suggestions; Dr. Charles R. Hursh, of the Appalachian Forest Experiment Station, George W. Craddock of the Inter-mountain Forest and Range Experiment Station, and Charles J. Kraebel and staff of the California Forest and Range Experiment Station, for review and criticism, particularly of the technical aspects of this publication.

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FIGURE 1.—Snow in the mountains—a life-giving source of water for springs, wells, and city mains.

during the most severe droughts does he worry about parched crops and seared pasture.

How different it is in the arid portions of the West! Here, where Nature is lavish with sunshine but niggardly with moisture, the struggle for existence is to a large extent a struggle for water. Here men once were killed in disputes over water rights. Throughout the Southwest, the farmer or rancher knows that until water can be brought to his land it is worthless for cultivated crops. Perhaps 20 to 30 unirrigated acres will feed a cow for a month or two during the year. Undeveloped, his land may be worth 50 cents per acre. Bring water to it, and its value jumps fiftyfold, a hundredfold, sometimes a thousandfold.

Sometimes We Have Too Much Water

Newspapers often tell us of floods in some parts of the United States. Nearly every year, on the great central drainages, heavy rains and melting snow cause the waters to pour out of mountains and plains, to turn brooks into torrents, and to swell quiet streams into wild, turbulent rivers. From Cairo to New Orleans, and from Pittsburgh to Paducah, the cry "River rising! River rising!" is a familiar yet fearful refrain.

Even where extensive and costly levee systems have been built, the rivers sometimes become too high or too swift to be restrained—and the results are devastating floods, like those on the Mississippi River drainages in 1912, 1913, 1916, 1927, 1929, 1937, and 1943. Communities are inundated, families flee from their homes, croplands are washed out, and transportation comes to a halt. Hunger, disease, and death stalk the raging waters.

Although given less publicity, the agricultural damage done by the many smaller, more frequent floods usually far exceeds the losses caused by the spectacular ones. There is good reason for this. It takes but a relatively small increase in water runoff from the uplands of small valleys to cause serious damage to farm lands on the narrow strips of rich, black bottom lands. The damage here is of two kinds—that resulting from the direct action of floods and that resulting from deposits of sterile silt, sand, gravel, and crumbled rock carried by floods.

In the Central States, ditches and drains cause the flows from spring rains and melting snow to run far more rapidly than in the days before white men settled on the land. Once, excess spring flood waters emptied into lakes and swampy lands, there to be detained for slow release into streams and rivers. Now, systematic drainage has virtually eliminated these natural reservoirs.

In the more rolling sections of the East, spring runoff was formerly absorbed and held temporarily in the porous soils beneath the unbroken expanses of forest. When large areas were converted to farm use, removal of the forest and practice of up-and-down-hill plowing deprived the soils of much of their ability to catch—and store—water. The more steeply the land slopes, the more serious this is.

The effects of eliminating or seriously disturbing the natural forest cover are shown in the gullied farm lands and widened stream channels found in some densely settled areas. Partly because the stream channels are more or less filled with material washed down from the uplands, and partly because storm runoff has increased, the channels are today no longer able to carry all the flow from heavy precipitation. This explains why the streams overtop their banks far more often than in the days before settlement.

Look at America's "Valley of the Nile," the lower Mississippi and its tributaries. Floodwaters in ages past helped build its fertility by slowly depositing rich topsoil from uplands, and it was not until our forebears commenced to clear the wilderness, strip the timber from the rolling hills, ditch the land, and

drain the lakes and marshes, that the floods became so destructive. Now the floods are more violent, sweeping over the occupied bottom lands and frequently covering them with coarse, worthless material. There were major floods on the Mississippi even in the days before settlement. But in recent decades they have come too often for our security and peace of mind.

Sometimes We Have Too Little Water

The same misuse of our land that helps to induce floods is also partly responsible for serious and costly shortages. When water from rain and snow is not stored in the soil but runs off quickly, there is no reserve to keep streams, lakes, and natural underground reservoirs supplied during the drier months of the year. Periodic decreases or failures of the water supply mean heavy expenditures by large and small communities for tapping new sources, and reduced or more costly electric-power output, with consequent temporary factory shut-downs. Many of the 80 million Americans who depend on public water-supply systems (fig. 2), and a considerable portion of those farmers in 17 Western States who look entirely to irrigation for their livelihood, have a vital interest in preventing water shortages.

Lack of a dependable year-round water supply prevents the establishment of new industries in a community. Many kinds of industries require great

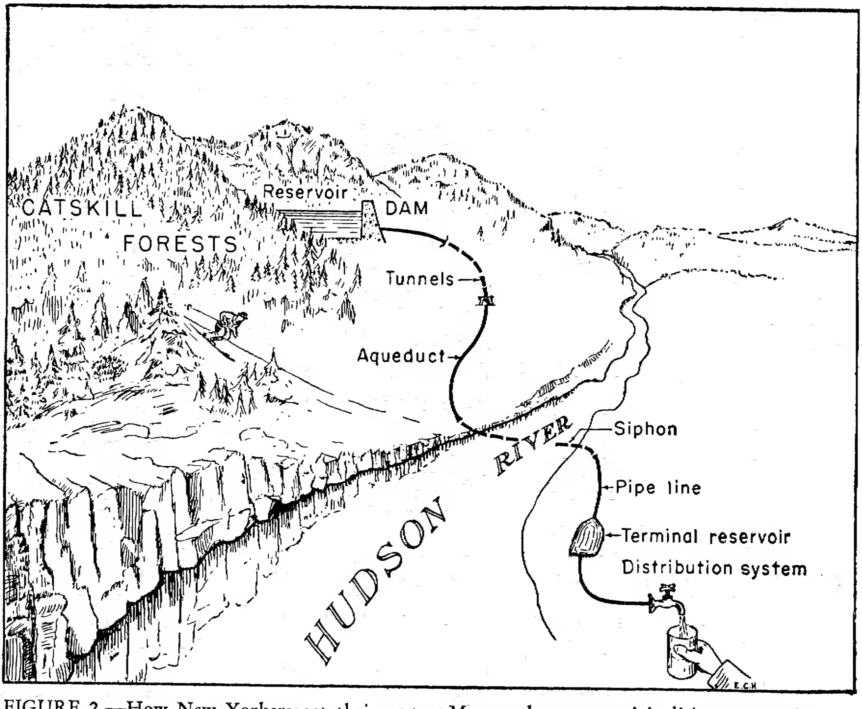

FIGURE 2.—How New Yorkers get their water. More and more municipalities are turning to forested watersheds to insure ample supplies of high-quality water.

quantities of water. One of the first questions to be answered in deciding where to locate an industrial plant is, "Can we obtain a steady supply of pure water here at reasonable cost?"

Lack of water sometimes causes serious crop failures on irrigated farms. It has actually forced an exodus of people from some regions—for example, parts of the Great Plains where recurrent dust storms and depleted soils have made farming difficult. It has imperiled California's Central Valley, one of our great farming regions. In some sections of this valley, even under the existing annual demands for irrigation water, investigations reveal that the ground-water level is lowering as much as 10 feet per year. Already, farm land totaling some 50,000 acres is reported to have been abandoned. And it is estimated that 380,000 acres now irrigated will eventually return to semi-desert condition unless water shortages can be overcome by providing additional supplies from streams rising in the distant forested mountains.

The East also faces water shortages. It is generally believed that underground supplies in the Mississippi and Ohio River Valleys, as well as in the Piedmont, are being drained faster than they are replenished. On many farms, wells go dry during summer heat and farmers have to fetch water long distances to keep thirsty cattle alive. In the summer of 1944, for example, some 6,000 Kentucky farmers sold their livestock because of lack of water. In Georgia, Virginia, and North Carolina farmers, towns, and industries require more water than is readily available. Wells must be drilled deep, and they are less dependable than shallow wells used to be.

How Soil, Forests, and Water Are Related

This discussion is mainly about the values of forests on watersheds. Just what is a watershed? Sooner or later much of the water from rain or snow appears as streams. Small at first, these upland watercourses become wider and deeper as they approach the valleys, where they combine to form our larger streams and rivers. The area that produces the water that appears as the flow of a stream is a "watershed" (fig. 3).

Watersheds are of many shapes and sizes and of varied slopes ranging from level to precipitous. Some cover millions of acres, like the Columbia or Missouri River drainages. And these, in turn, may be subdivided into tributary areas that may be as small as a few acres.

Watersheds display a variety of climatic and geologic conditions. The rainfall on a large watershed may be less than 18 inches a year in some sections and 80 inches in others. The higher slopes may be steep and bare, underlain with solid or crumbly rock, while the lower, gentler, shorter slopes may rest upon porous glacial drift, cavernous limestone, or perhaps fractured-rock formations. The soils may vary from thin sands that take water readily—but let it out equally fast—to deep, tight clays that absorb water slowly, swell up when wet, and crack open when dry.

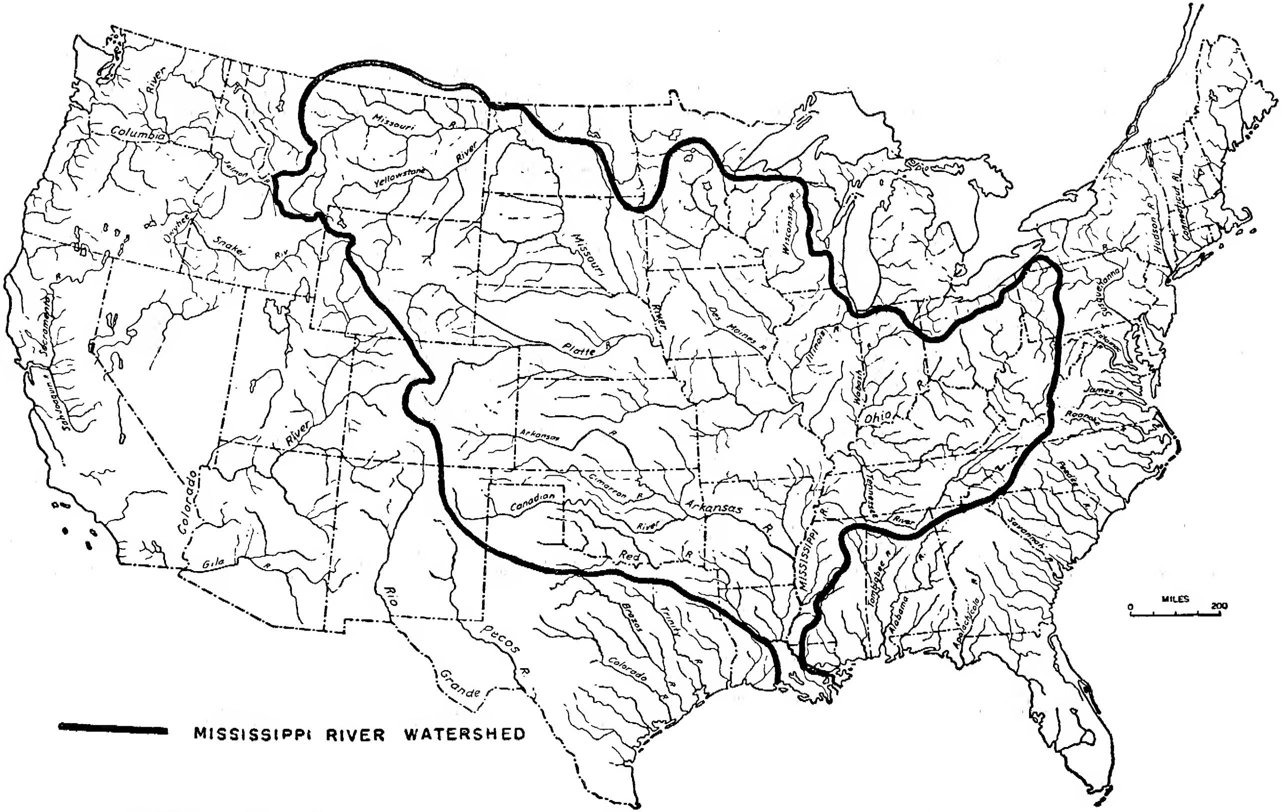

FIGURE 3.—Major drainages of the United States, showing the relative extent of the Missis-sippi River watershed.

The plant cover also varies. It may be of the forest, shrub, or grassland type, ranging from thick to sparse. Portions of some of our watersheds, especially in the dry western regions, have little plant growth. Examples of this condition are the Mohave Desert in California and the Jordan River Valley in Utah. Other watersheds, by contrast, are covered with dense forests clear to their tops, as in the Great Smoky Mountains of Tennessee and North Carolina.

In undisturbed natural conditions, the soil, cover, and moisture supply on a watershed tend to be in balance. Plant growth is adjusted to the amount of rainfall, and stream channels to the runoff they must carry. When man ignorantly or carelessly upsets the balance by destroying much of the plant cover, perils arise . . . often resulting in dust bowls, spreading deserts, ruined valleys, silted reservoirs, recurring water shortages, polluted rivers, and ravaging floods.

"To Rule the Mountain Is To Rule the River"

Forest land (fig. 4), in addition to producing timber, forage, and wildlife, has enormous value as a regulator of water flow. In some localities this value far exceeds that of any other forest product or service (fig. 5). Not only do forest soils retain moisture and store water; they also have much to do with controlling water movement both on and beneath the surface. This often spells the difference between clear, steady streams fed by dependable underground sources, and erratic flows of muddy water, rising rapidly after rains, then shrinking as rapidly, leaving only dry river beds.

Let us go outdoors and take a close look at a healthy forest. You will soon notice that it is far different from a grazed farm wood lot, a neat and well-trimmed city park, or an abandoned field with scattered trees, broomsedge, and briers. The ground is softer, the air cooler in summer and warmer in winter than in a park, wood lot, or open field. On the surface and within the soil, there is teeming plant, animal, and insect life, a veritable beehive of activity. Hence the forest is not merely a collection of trees; it is an integrated biological community with its own special climate, characteristic undergrowth, and topsoil.

The forest floor is protected by the crowns of trees at different heights and the mass of shrubs and ground plants below. The surface itself is a mat of dead leaves, twigs, and other plant remains. Beneath this loose litter is a layer of partly decayed vegetation, and below that, a mass of more or less completely rotted organic matter.

Underneath these organic layers is mineral soil, also occurring in layers. The top portion is considerably enriched with organic material and shot through with growing and decayed plant roots and the minute channels of innumerable earthworms, mites, insect larvæ, bacteria, and fungi, working constantly throughout the soil. All this biologic activity keeps the soil porous

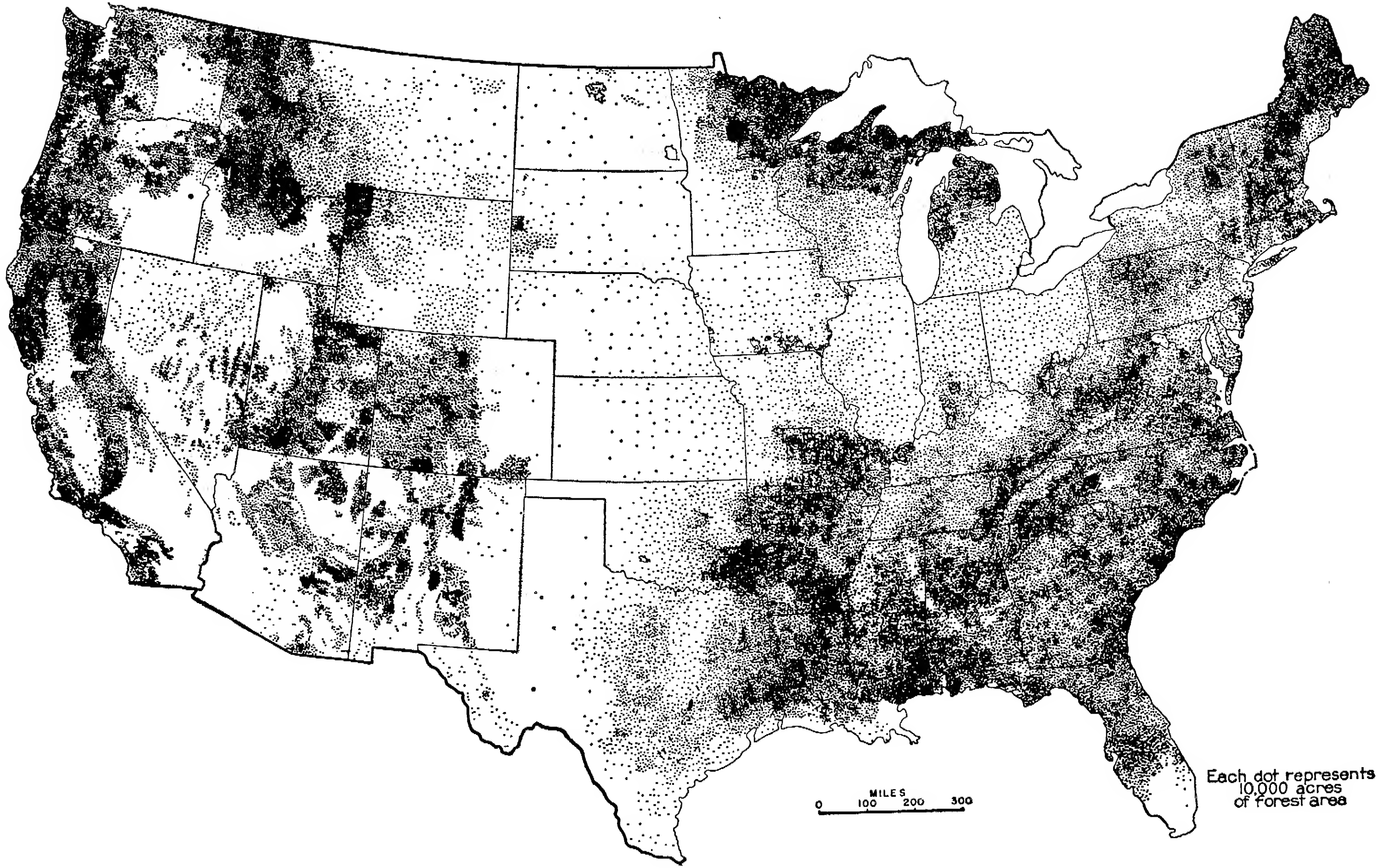

FIGURE 4.—Distribution of forest lands in the United States.

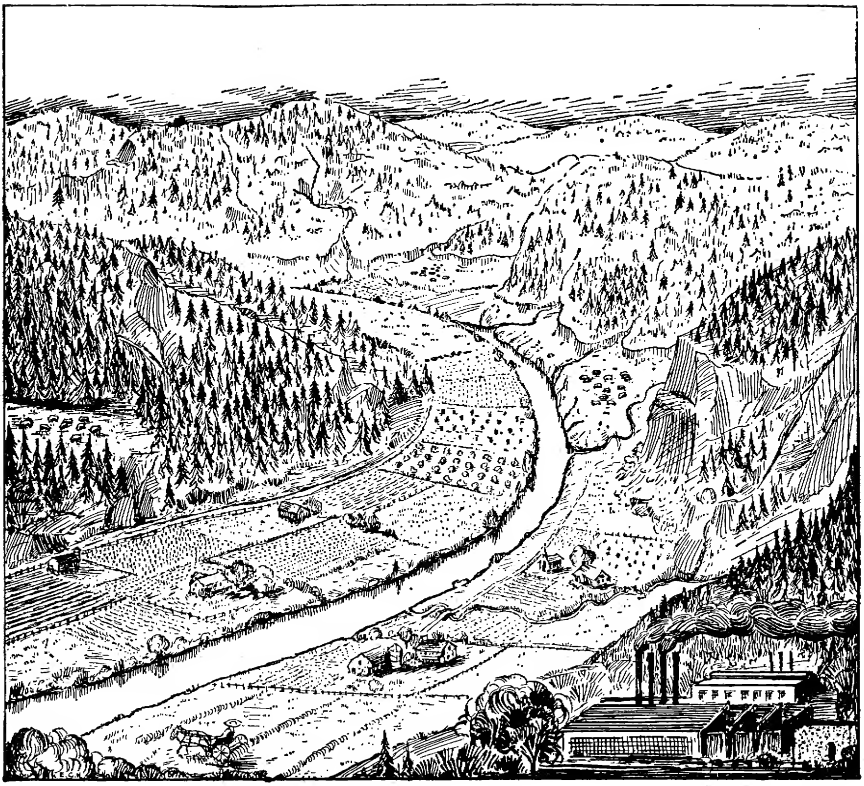

FIGURE 5.—A forested watershed. "To rule the mountain is to rule the river," says a Chinese proverb.

and gives it a crumbly structure ideal for holding, storing, and filtering large amounts of water.

Below these layers is the subsoil, sometimes derived directly from the weathering bedrock beneath. Except for the penetration of deep roots and the burrowing of insects and rodents, it contains few openings and is a much tighter structure, so that ordinarily the subsoil is incapable of detaining as much ground water as the topsoil.

Thus the speed and volume of water movement through the soil depend on its structure and the shape and continuity of the large pore spaces formed by plant roots and by animal and insect activity. Any given soil can store only a certain amount of rainfall. Hence the amount of water already in the soil determines how much will be stored during any particular storm—provided the water is able to get in. Good forest soils, which take water quickly, can hold 50 per cent or more of their total volume. This means that soil 8 feet deep may store about 4 feet of water.

Snow accumulation and melt is also influenced by good forest cover (fig. 6). Protected against sun and wind, snow will remain on the forest floor from 1 to 5 weeks longer than on exposed areas. Also, more of the melting

snow is absorbed by the loose, porous, and frequently unfrozen forest soil than the soil of open fields, which is commonly frozen. Thus valley farmers are assured a more constant supply of irrigation water in the growing season.

When rain falls in the forest, part of it clings to the leaves or needles of trees and plants, where it later evaporates, and some trickles down the stems and plant stalks. In a hard or prolonged rain, a considerable amount of water falls directly on the forest floor, filtering into the topsoil and gradually filling its pores. For use in the life processes of the vegetation, some of this water is later pulled up into the stems and leaves before it is transpired into the air.[2] If the ground cannot take in all the water that reaches it, some runs off over the surface.

Another part of the rain moves downward to become a part of the permanent water table that supplies our springs and streams (fig. 7). After the rain stops, slow drainage through the soil continues until only as much water is left as can be held there against the pull of gravity. This percolated, or ground, water is the major source of many western streams.

To Abuse the Mountain Is To Ruin the Valley

Healthy forest cover, although much more effective in restraining floods in the smaller than in the larger valleys, exercises an important function even

[2]Naturally, more water is pumped up by vegetation and transpired during the growing season than in winter.

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FIGURE 6.—Saturated soil and snowbanks in the open woods hold water for slow release into the ground. Streams serve as aqueducts.

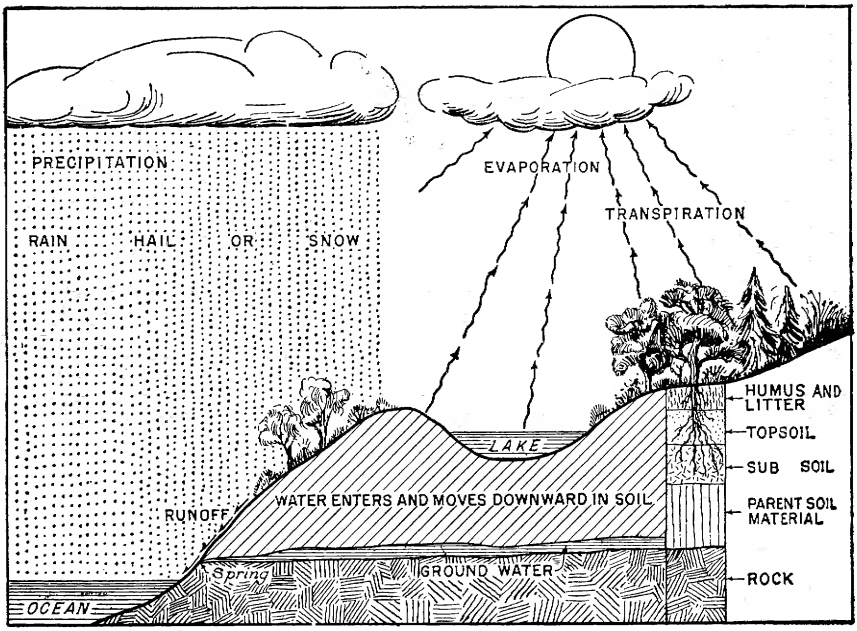

FIGURE 7.—Water comes and goes from earth to sky in an endless cycle.

in the heaviest storms and during major floods. It protects the soil, filters the water, and lessens the debris load of the flooded stream channels. Without this cover the major floods would be even more disastrous, the water far muddier, and destructiveness far greater.

As mentioned previously, the plant cover, soil, and stream flow on a watershed naturally tend to be in balance, if undisturbed. When a large portion of the plant cover, litter, or humus is destroyed by fire, or removed by destructive logging or trampled by grazing animals, marked changes appear. Exposure of the forest floor to wind and sun is increased. Trees break or blow down. The remaining litter and humus dry out, and the busy organisms at and below the surface gradually disappear. Soil becomes more compact and resists the entry of water, so that erosion often begins. The result is a seriously unbalanced forest community that permits less water to be taken into and stored in the soil than before—to the detriment of downstream farms, towns, and cities.

Fire is one of the most powerful enemies of the forest (fig. 8). Even small fires consume considerable amounts of litter, causing increased runoff until new plant growth appears. A single severe fire may kill all the vegetation. Often the heavy damages wrought by forest fires to soil and water resources are not obvious at first. Only careful and repeated measurements of accumulated fire losses—reflected in decreased fertility of the land, hence slower growth of plants; inadequate moisture for uplands; and short water

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FIGURE 8.—When fire destroys the forest, flood and debris flows are often inevitable. The above burned and devastated area is a blot on the landscape and a liability to man.

supplies for communities, farmers, and industries downstream—can reveal the full extent of the damage.

Rough estimates indicate that as much as 10 million acres of timberland are cut annually in the United States. Careless logging methods leave 8 of every 100 of these acres stripped of trees and young growth. On many valuable watersheds, improper logging has killed the small trees, dissipated the humus, and scarred the soil with skid trails (fig. 9). Severe fires have often started in the logging debris and burned all vegetation to the ground. Careless logging, even if not followed by fire, contributes to costly floods and deposits of sediment, irregular stream flow, and sometimes stream pollution—all of which last until new growth comes in to protect the soil, reestablish the vegetative cover, and rebuild the humus that attracts soil organisms.

It takes many years to restore the soils and cover of a damaged watershed. Any kind of vegetation is beneficial on bare, eroding land, but to bring back an eroded area to its original water-storage capacity takes decades, sometimes centuries. Over 100 years are required for Nature to replace the trees and humus of beech-birch-maple forests in the northeastern United States after destruction by fire. After clear cutting, even without fire, the humus decreases to half its former depth in 30 years, and does not build back fully for 80 to 100 years.

Overgrazing in the forest also has serious consequences. Too many cattle or sheep, deer or elk (fig. 10) feeding on a given area will mangle or kill young trees and shrubs, consume most of the forage, and pack down the soil. Exposed soil and drying winds, less hindered in the more open forest, steal moisture from the larger trees, thus increasing their susceptibility to insect attack, disease, and windthrow. Even when grazing is reduced, full recovery of the pastured woodland is usually very slow; in the Northeast it takes

Nature as much as 30 years after the cattle have been removed to bring a depleted woodland grazing area back to healthy condition.

Fire, destructive logging, and overgrazing are not the only enemies of watershed forests. Less common but equally harmful is the smelting of ore. Poisonous fumes from copper and silver smelters in certain localities in Tennessee, California, and Montana (fig. 11), have completely killed vegetation for miles around. An area of 10 to 12 square miles around Ducktown, Tenn., has been practically denuded of plant growth; 1 to 5 miles beyond this zone the vegetation is badly injured or stunted; and for some distance beyond, the forest cover is unthrifty, with many dead or dying trees.

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FIGURE 9.—An example of bad watershed management. Clear cutting and skidding logs downhill induce erosion. Rain, falling on the exposed soil surface, speeds up runoff, washes away the soil, and deposits sterile materials on fertile farms below.

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FIGURE 10.—Deer or elk thrive best when their numbers are kept to a level that will permit the forest growth to furnish adequate forage, water, and shelter. An excess of deer or elk not only impairs watershed values, but endangers their health, and in severe cases causes disease and starvation.

Some road building has been harmful to forested watersheds, particularly in rugged mountain areas requiring deep cuts and fills. The location, design, and construction of roads and trails must be carefully planned, else the forests will be injured by opening drainages or by exposing unstable soil or rocks. Improper construction or design may result in windfalls, dead, dying, and broken trees, sheet and gully erosion, landslides, ruined fishing streams, or diminished scenic values. Where slopes are steep, rainfall intense, soils thin or subject to landslips or slides, rocks fractured or crumbly, or where the forest is old and dense and the trees shallow-rooted, it may be wise to avoid graded road and trail construction. Unless the consequences of excavation and drainage are carefully considered in laying out a road or trail, serious erosion hazards may be created.

Sedimentation—the settling out or deposition of eroded materials by waters flowing from abused watersheds—shortens the useful life of reservoirs and makes necessary costly, repeated dredging of navigable stream channels. Furthermore, sediment deposits on clean gravel beds of mountain streams destroy the habitat of valuable game fish. This means a serious loss to fishermen and places of business that serve them.

F247623

FIGURE 11.—One of the tragic byproducts of an industrial era. Once heavily timbered, this mountain east of Butte, Mont., has been virtually stripped of plant growth by the fumes of copper smelters and ruined for water-control purposes.

Denuded Watersheds Make Us Poorer

Let us look at one example of the lack of protective vegetation. La Cañada Valley in southern California is located at the foot of the rugged San Gabriel Mountains, where annual rainfall is so low, and the summers so hot and dry, that only chaparral can grow on the steep slopes. During the dry season of 1933 the careless flick of a match started a fire. The brush cover was completely burned over on an area of 7½ square miles, reducing the capacity of the soil to take in water as well as the stability of the soil mantle itself. Several months later, on New Year's Eve, torrential rains began. Unable to filter into the bare soil, the downpour from the sky rapidly became destructive surface runoff, loosening the exposed soil and crumbly rock and carrying masses of debris down the canyons.

The savage waters swept everything in their path, from fine silt to great boulders weighing over 60 tons, tearing them from mountain slopes, or lifting them bodily from the canyon bottoms. When the waters reached the valley, they spread out fanwise over an area of 3 square miles, equal to 60 city blocks one way and 20 blocks the other. It wasn't a major flood, as floods go. But within a few hours over 400 homes were damaged, gardens and improvements ruined, roads and main highways blocked, and death and sorrow came to scores of families.

The nearby unburned slopes didn't escape the force of the hard rains, but practically all the floodwaters and the 600,000 cubic yards of debris came from the burned area (fig. 12). Studies made after the storm revealed that, acre for acre, the flow from the burn was over 50 times that from the unburned part of the watershed.

Other southern California communities constantly face similar danger. The headwaters of the Santa Ynez River in Santa Barbara County are mainly within the Los Padres National Forest, an inflammable, brush-covered area of rugged slopes and shallow soils. Here the sequence of fire and rain has contributed to the ruin of 1,000 acres of fertile Lompoc Valley land—the flood of March 1938 alone caused downstream damages amounting to $340,000. Heavy sedimentation has also damaged Gibraltar reservoir, which supplies Santa Barbara with drinking water. Despite the dams built to catch debris and the revegetation of scarred slopes, this reservoir has filled with silt so rapidly during its 23-year life that today it has room for barely more than half the water it was built to hold. Repeated burning has so thinned the protective watershed cover that silting and other downstream destruction cannot be checked unless fires are rigidly controlled.

On the rich Yazoo River flood plains in Mississippi, floods occur almost every year. Some of the smaller tributaries of this river spill over their banks 15 times a year, depositing the products of eroding hills on 1 acre out of every 20 they traverse. As a result, long stretches of weedy grasses, brush, and poor swampland may be seen where, not many years ago, there was high-yielding cropland.

In recent years the average flood damage to crops, livestock, and property in the Yazoo River basin has exceeded $1,500,000

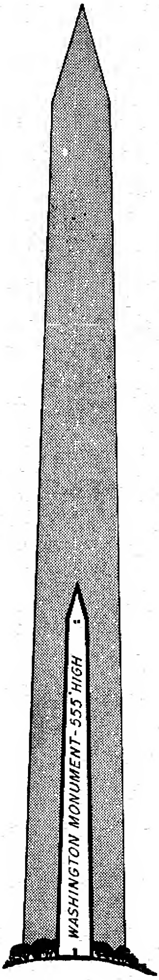

FIGURE 12.—The debris accumulated on 3 square miles of flooded land in La Cañada Valley is equal to 16 times the volume of the Washington Monument.

annually. The subsoil has been bled off the Yazoo hills and laid down on top of the previously fertile bottoms. Large areas have been abandoned because of repeated sediment deposits or soil scouring, reducing per-acre returns on some farms by more than 50 per cent. To date, 750,000 acres have been ruined and another 1,500,000 acres damaged by erosion in this once-fertile basin (fig. 13).

One of the major reasons for the severity of the May 1943 floods in the central Mississippi Valley was the unsatisfactory condition of the 280,000 square miles of land subjected to the heavy spring rains. The United States Department of Agriculture's watershed investigations revealed severe erosion

on from 25 to 50 per cent of the area, and depleted soil cover on all but 5 per cent of the woodland acreage. Damage to agricultural areas from scouring and deposition of sterile materials was greater than from the floodwaters themselves.

Overgrazing is often a direct forerunner of floods. This was strikingly illustrated in the densely inhabited valley between Ogden and Salt Lake City. Here a few hundred acres of overstocked mountain range, on which the plant cover had been worn dangerously thin, was primarily responsible for over $1,000,000 of flood damage in 8 years. During that period, there was an average annual loss of $250 in farm land and buildings for every acre over-

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FIGURE 13.—Eroded land is sick land. Once productive forest, this gullied field on the Yazoo upland in the State of Mississippi is now wasteland—a source of serious flood damage downstream.

grazed. Yet the grazing income from this land was perhaps 25 cents per acre annually.

Overgrazing is sometimes responsible for reduced or irregular water supplies. Minersville, Utah, knows this all too well. A few years ago, summer storms on the overgrazed mountain forests above the town resulted in sedimentation of the main irrigation canals. That summer it was not only difficult to distribute the water among the lateral canals, but Minersville could obtain clear water for only 8 days in the entire crop season. A fivefold increase in irrigation assessments was necessary to pay for removal of the sand and gravel in the ditches.

Obviously, overstocked ranges on vital watersheds don't pay. Everybody loses—the livestock operator whose returns shrink as forage is depleted (fig. 14), the valley communities that suffer damage in times of flood, the counties that lose tax revenues, and the State that supplies relief to distressed families.

F333221

FIGURE 14.—Erosion and runoff problems originate on overgrazed lands. Damaged mountain meadows like this one in California will be entirely destroyed unless erosion is checked by expensive measures.

Many growing communities, faced with mounting demands for water for home and industrial use, are finding it expensive to filter or settle the great quantities of mud from their supplies, obtained from streams. Usually these streams carried much less silt or mud, the year round, in the days before vegetative cover on their watersheds was badly abused.

Because of the neglect and abuse of upland vegetative cover by past generations, it has been necessary in recent years to undertake large-scale and costly watershed-improvement programs. Plans are under way for spending in the Mississippi Valley alone hundreds of millions of dollars for flood-control reservoirs, channel improvements, and the like; but these will not yield their maximum benefits unless land management is improved—unless, above all, our watersheds are wisely used.

Our Watersheds Need Greater Protection

Of our 630 million acres of forest land, some 320 million acres are of major importance and about 150 million acres are of moderate importance in the protection of watersheds. These may be called protection forests. Those of major importance are located at the higher elevations in regions of scarce or variable water supplies; on steep slopes subject to heavy or concentrated rainfall; on areas with excessive and rapid snow melt; and where bare soils erode quickly. Forests of moderate importance occur on the gentler slopes; on

lands subject to scanty or moderate rains; and where the soil is not highly erodible and can be quickly clothed with new plant growth after fire or logging.

Since one-sixth of the total land area of the United States is covered with protection forests of major importance it makes a great difference to all of us whether the vegetative cover—trees, brush, grasses, and other plants—is in poor or good health. Protection forestry recognizes the importance of handling the forests so as to maintain beneficial conditions for vegetation, soil, and water resources; in other words, to protect all the natural values of watersheds that are essential to people (figs. 15 and 16). Some of our important watershed forests are used and maintained in such a manner; others are not.

Of the 470 million acres in forests of major to moderate watershed value, some 200 million are owned by the public—that is, by the United States, the several States, counties, and towns. (Our national forests alone supply most of the water for the semiarid regions of the West, and for hundreds of communities in the East.) The rest are in private holdings of all sorts, ranging from small, scattered farm woodlands to commercial timber tracts of several hundred thousand acres.

Though much protection-forest land is publicly owned, not all of it is managed so as to maintain the best standards of water-resource conservation. It is true that on most public forest lands fire control is becoming increasingly effective, and cutting, where permitted, is usually supervised. But on many areas, much improvement is needed. Overgrazing by deer, elk, or livestock has resulted in serious erosion and accelerated runoff; or logging and improper road and trail construction have induced erosion and landslides, and caused

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FIGURE 15.—Forestry for watershed protection. This white pine plantation on an eroded old field above a Pennsylvania reservoir has not only prevented sedimentation by providing a soil-protective cover, but will also aid in providing clear drinking water to nearby communities.

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FIGURE 16—Boulder Dam, a multipurpose engineering structure, provides flood control, power, and other benefits of tamed water. The water that turns the gigantic turbines originates in the forests of the Rocky Mountains. To keep the reservoir from filling up with silt in too short a time, the whole watershed above it must be brought into as healthy a condition as possible.

silting of streams and reservoirs. (See fig. 17.) On the whole, however, soil, water, and flood-damage problems are gradually being met on public forest lands, and considerable effort is made to overcome the unfavorable effects of past misuse.

On private forest lands the situation is less satisfactory. A substantial part is in poor condition for water conservation, and little if any thought is being given to the kind of management that is necessary if we are to maintain our valuable water resources.

Fire losses are excessive even on much private land under organized fire control, while protection is entirely lacking on millions of acres that are high in water-resource values. On some of this land, burns occur as often as twice a year, steadily deteriorating the forest cover and soil; on much of the grazed land, little attention is paid to the possible effects of this use on watershed

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FIGURE 17.—Watersheds: good and bad. The reservoir in *A* should have a maximum useful life because the forest on its watershed is well managed. The dam in *B* was built to catch silt from a burned watershed and thus to keep it out of a reservoir downstream.

values; and on most timberlands cutting and logging methods adjusted to watershed-protection needs are virtually unknown.

Much forest land has been cleared for agriculture and worn out or abandoned, or else seriously damaged by overgrazing and repeated burning. Such damaged lands include at least 15 million acres in the Piedmont and Upper

Coastal Plain of the Carolinas and Virginia, 20 million acres in California, and many millions more in the Appalachian Mountains, Central States, Mississippi Valley uplands, and Rocky Mountain areas. Many of these lands should be reforested, protected against fire, and above all, managed continuously to restore their soil and water values.

Let us examine the contrasting experiences of two neighboring Utah communities: Centerville and Farmington. Both are situated at the foot of the Wasatch Mountains between Ogden and Salt Lake City. Each depends for a vital water supply upon a few square miles of steep forest and brush lands. Years past, the people of Centerville acquired or leased the headwater areas and greatly reduced the number of livestock permitted to graze on them. In addition, fire control was intensified and the vegetative cover was improved.

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FIGURE 18.—Contour trenches supplementing revegetation on overgrazed, burned-over slopes of the Wasatch Mountains have stopped soil erosion and checked debris movement. Runoff which otherwise would create floods now is caught in the furrows and augments ground water supplies.

This forethought has yielded rich dividends. The stream flow in Centerville Canyon has remained consistently clear and useful. No destructive floods have occurred since settlement began, nearly 100 years ago.

Farmington, unhappily, neglected its mountain slopes, allowing them to be burned and overgrazed. As the plant growth became weaker and sparser, soil losses increased and a deep and extensive gully pattern was formed. In 1923, and again in 1930, mud and rock flows roaring out of Farmington and other canyons took lives, ripped up the railroad and highways, and buried homes and farms.

Fully aroused at last, the people of Farmington in 1933 sought relief in upstream protective measures. It was too late, however, to remedy matters by simply regulating grazing and controlling fires. In addition, it has been

found necessary to install costly contour trenches (fig. 18), reseed or plant bare spots, completely exclude all livestock, and build large debris-catchment basins downstream.

Centerville goes calmly about its business, confident that its inexpensive watershed-management measures will continue to protect it against floods. Its neighbors, however, have not only paid for their neglect in serious losses, but have also been further burdened with the cost of an expensive remedial program.

Engineering Works Are Also Needed

Because there is a limit to how much water even the best vegetative cover and soil can hold back, the control of runoff must be supplemented in many cases by dams, dikes, or other channel improvements. The long-time usefulness of such structures, in turn, depends on a healthy forest or brush cover upstream, particularly where there is danger that reservoirs will silt up. On the other hand, engineering devices such as diversion ditches and small silt or debris catchment basins may be needed on seriously eroded lands. These help stabilize the soil and conserve moisture for use by plants until the new growth is well enough established to control runoff and erosion by itself. Sometimes, too, reservoirs are required to handle excessive runoff from heavy rains on eroded soils that become saturated or frozen and can no longer afford flood protection. It is obviously wiser and less costly to hold back high water and reduce or prevent floods, than to fight the floods and clean up the wreckage.

Many types of special engineering devices—dikes, jetties, sills, diversion works, check dams, gully plugs, spreaders, wattles, and terraces—are useful in directing water flow, controlling erosion, and stabilizing mining debris or various kinds of newly exposed earthworks. Such improvements must be designed on sound engineering principles, based on an accurate knowledge of the amount and behavior of rainfall and runoff on the watershed. In the long run, however, mechanical works must be supplemented by good vegetation and careful and continuous cultural practices to assure the soil full protection against water's untamed force, and thus permit us to derive the maximum benefits from its flow and energy.

Forestry to Conserve All Watershed Values

Sensible, well-balanced management of watershed forests recognizes the need for protection of soil and cover, increase of water taken into the soil, and reduction of evaporation losses, as well as continuous timber crops. It takes into account the fact that clear water, which furnishes moisture to the forested slopes, is also needed by downstream communities.

The first step in this kind of management is full consideration of all the values present, so that the less important uses will not be favored at the expense of the more important. For example, to manage some watershed forests

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FIGURE 19.—A sparkling mountain stream can be a thing of beauty and a joy forever, if the watershed above is maintained in a balanced condition.

for timber production alone would make it necessary to ignore many of the requirements of desirable soil-cover-water relations.

Thus, in some types of forest, clear cutting, especially if followed immediately by natural regrowth or by planting, is a perfectly sound method of producing continuous timber crops and does not seriously damage protection values. But in others, clear cutting reduces the ability of the forest to provide

clear, regular stream flow because it decreases the organic material on the forest floor, and the amount of water stored in the various layers of soil. In such forests light and frequent cuttings, rather than a heavy cut at one time, help to retard flood flows and produce larger continuous supplies of good, clear water (fig. 19).

In some forests, the landowner might obtain maximum returns from timber by cutting out the hardwoods, such as oak, hickory, birch, or maple, and encouraging the faster-growing or more salable softwoods, like pine or spruce. On the other hand, the protection of downstream farms and communities from floods might be better attained by maintaining a dense stand of mixed hardwoods, which produce the best humus and improve the porosity and storage capacity of the soil.

Rocky Mountain snow fields support pine as well as aspen, a species of relatively little commercial value. Good management for timber dictates removal of the aspen and encouragement of the pine. But if water is more important than timber, the aspen should be encouraged rather than the pine since its bare crowns allow more snow to reach the ground where it can be stored until spring melting time for downstream users (fig. 20).

Again, in some forests the present amount of protection against fire might be adequate to insure a future timber supply, but not to conserve or rebuild watershed values. Where the plant growth is of little value for timber, as in the sprout forests in some parts of the Appalachian region, or on the brush-

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FIGURE 20.—In Arizona lush citrus groves rise on desert land only because water is available during the summer from melting snows in remote mountain forests.

covered slopes of southern California, the most intensive fire protection is needed if we expect to minimize flood and debris flows.

Research and experience show us how to use protection forests for many purposes. We must know how they "operate"; determine the important uses they can safely withstand; and finally, put into actual daily practice a program that balances the different acceptable uses. In many areas protection forests with proper management can serve forest industries, livestock operators, farmers, recreationists, cities, towns—in fact, everybody. But in others watershed values may be so high, and the danger of impairing the forest cover so great, as to require the strictest control over all woods activities. European countries have followed this policy in the Alps and elsewhere, and so has our Government in some areas within the national forests.

Where there are no flood-control dams we must rely upon the water-holding function of forests to help keep rivers or streams in check. Many valleys in the United States need flood protection, but engineering works would be too costly, or would flood out valuable farm land. Here we must look upstream and apply watershed management measures to the headwaters, where the troubles originate. As we have seen, the amount of runoff after a rain depends on how much water can get into—and be detained by—the soil. Trees and plants pump out some of the water, so that when more rains come the forest soil has ample room to receive them. This reduces storm runoff and helps to protect downstream farms, towns, and cities from floods.

The water-control function of forest land varies according to the kind and density of the plant cover. Even virgin forests, for example, are not always the most satisfactory for all purposes, especially if water supplies are not ample. Where water supplies are derived almost entirely from snow melting at high elevations, as in the Rocky Mountains, there may be disadvantages in maintaining dense, unbroken stands of pine, spruce, or fir. The crowns of such trees trap and hold much snow, reducing the amount that reaches the ground and later melts and works down into irrigation canals or storage reservoirs. Such forests also draw on what little summer rainfall occurs, and transpire water that might otherwise furnish stream flow in the critical dry season. Experiments by the United States Forest Service have shown what a surprising amount of water is held back by dense forests or even individual large trees. In Colorado's high mountain forests, large, limby pine trees were felled and small openings were made in dense stands—openings not large enough to change the character of the forest or start soil erosion. As a result, the amount of water available for stream flow was increased as much as 5 inches deep, or on the basis of a square mile of forest, 267 acre-feet. This would provide 87 million gallons of water per square mile for domestic and business use, enough for a town of 25,000 people for 5 weeks. Changes in the treatment of a watershed forest can therefore make great differences in ground water supplies and stream flow.

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FIGURE 21.—Healthful lake recreation is but one of the products of a well-managed watershed.

Traveling across the United States, we find a variety of water situations. Some communities require both flood protection and ample water supplies. We can provide both by building reservoirs downstream to supplement the natural soil reservoir, and by modifying the forest cover upstream to reduce water consumption by vegetation. If flood protection alone is the primary objective, we must encourage the kind of forest growth which draws the maximum volume of water out of the soil in the shortest time after rainfall, thus keeping up its storage capacity.

To sum up: managing forest land for timber products alone, no matter how efficiently, may not always bring the fullest benefits to all the people. The public will gain most from management which recognizes the varied role of watershed forests in providing (1) numerous forest products; (2) good, clear water supplies; (3) flood and erosion control; (4) an ideal habitat for wildlife; and (5) attractive recreational opportunities (fig. 21).

In managing forest land we must determine by careful surveys the value of each of these important uses. Only then are we ready to apply the right kind of forestry. Any activity that endangers the health of the protection

forest, or threatens to speed up runoff and erosion and encourage floods, silting, and muddied, polluted streams must be firmly restricted or eliminated.

Much more by way of improvement in management practices on our watershed forests can be accomplished than is generally realized. We are still a long way from doing the things we know can and should be done. And as more research is applied to our growing watershed problems, new or better methods of solving them will be discovered.

How We Can Help Safeguard the Nation's Watersheds

In a broad sense, all of us are responsible for maintaining our watersheds in good condition—timberland owners, woods operators, farmers, ranchers;

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FIGURE 22.—In the forest primeval, nature is in balance. Our job is to use the forest for man's manifold purposes without destroying this balance.

hunters and fishermen, berry pickers, tourists, hikers, campers; and even city folk who seldom set foot on the wooded earth.

The health and economic security of nearly all Americans depend to a great extent on how well our forests are managed. Just as costly illness or a surgical operation may follow persistent neglect of the simple rules of personal hygiene, the abuse of watershed forests is apt to require expensive measures and perhaps decades of time to restore forest health which is so essential to the Nation (fig. 22). All classes of landowners and users must

work together to help enforce the simple rules of "forest hygiene." For example, we must be extremely careful not to throw away burning material or allow camp or picnic fires to burn unattended.

Forest owners are usually the first to reap the fruits of good management. Theirs consequently is the initial obligation to practice the kind of forestry that will safeguard the public's stake in forest land. Because they have a serious public responsibility, these landowners must employ every means to prevent fire, eliminate improper cutting and log-skidding practices, and minimize grazing damage. The general public, to protect its own vital interests, should demand that forest owners observe this obligation.

Urban water users and valley dwellers, though remote from the watershed forests, usually suffer the consequences of damaged uplands. These groups should demand, in particular, that landowners and users take the needful steps to prevent erosion and rapid runoff; otherwise, their general health and well-being may be imperiled. They also have responsibility for not wasting water, or using it without considering others' needs.

Where landowners or users are unwilling, or unable, to manage the forest so that it will produce water, timber, and other products or services in continuous abundance, the public must help devise and enforce fair and intelligent corrective measures. Where the private owner finds it unprofitable to maintain a good forest cover, or to restore a damaged watershed, even with a reasonable degree of public aid, it may be advisable for the public to acquire his land and put it under the kind of management necessary for the common good.

As we learn more and more about our water-resource problems and appreciate the increasing value of forests for watershed protection, we can expect the public interest in proper forest management to become more pronounced. Because communities, farms, and industries suffer when the forests are mistreated, and the public treasury usually pays for the damage, each of us must share responsibility for safeguarding the Nation's precious watershed forests.

—U. S. GOVERNMENT PRINTING OFFICE: 1950

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